Physics Package Confidence: "ONE" vs "1.0"

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The "reliability" of the nuclear explosive package of a stockpiled nuclear weapon has historically been stated to be "ONE," with the intent to convey very high confidence that a device that was properly constructed and that had been properly handled would perform as expected on receipt of the appropriate arming, fusing, and firing signals. We report on recent work clarifying the basis for assertions of confidence when applied to high consequence systems in the context of Quantified Metrics and Uncertainty (QMU) [1]. Previous work on QMU has used a conservative approximation that assigns a confidence of "ONE" or "Not ONE" for nuclear weapons. We extend QMU to a fully probabilistic setting, in which confidence in performance can be assigned a probability between zero and one. We use this more general formulation to examine the assumptions underlying the more conservative model.

The approach to confidence that has been taken historically is based on conservative bounds on uncertainty, grounded in nuclear test results, and supplemented by scientific judgment. This has led to a binary assessment of confidence as "ONE" (we have high enough confidence that the weapon will work properly to allow certification) or "Not ONE" (we do not have sufficient confidence for certification). A confidence assessment of "ONE" is thus not an assertion that the probability of some event (successful operation of a nuclear weapon) is 1.0. It is rather a statement that the balance of evidence is sufficient to support certification.

The questions that must be answered to maintain confidence in the stockpile include assessments of weapons' behavior in circumstances where (1) aging, engineering flaws, or manufacturing defects result in stockpile devices that fail to meet original specifications, or (2) nuclear design flaws, apparent or suspected, come to light. In addition, certification of new designs and/or new applications of existing devices could be desired if deemed necessary for national security. Under a comprehensive test ban, the design laboratories must attempt to answer this range of questions without further nuclear tests. It seems likely that this can be done with the requisite confidence for some questions but not for others. To push the envelope of what can be reliably certified without nuclear testing as far as possible requires advances in predictive science across a broad front including experimental, modeling, and simulation capabilities.

The most crucial role of any certification methodology is to clarify the choices and judgments made in deciding whether or not to certify a device at all. The determination that a device fully meets the weapon system military characteristics, and the predictions of the range of its performance are qualitatively different products of the certification process. Thus, while reliability and performance are both important, they are not the same thing for a nuclear weapon system.

Because of the potential consequences of a weapon failure, a policy of strict conservatism is usually adopted. This is implemented in part by requiring that a certification be based on persuasive evidence that the device will work, as well as on the absence of significant evidence that it might not work. Note that conservatism requires judgment in its application. Both excessive and insufficient conservatism have their costs. The QMU method has been introduced to provide a systematic and explicit framework for explaining the scientific basis for confidence in assessments of the performance, safety, and reliability of nuclear weapons. QMU is built on salient characteristics of a weapon's performance, each of which is known as a metric, derived from an analysis of experimental data and computer simulations. Requirements for robust operation for the metrics are termed "gates," and the margins of interest to QMU are the amounts by which the metrics exceeds the requirements (see Fig. 1). Gates and margins are well suited to inform the binary decision of whether or not to certify a weapon.

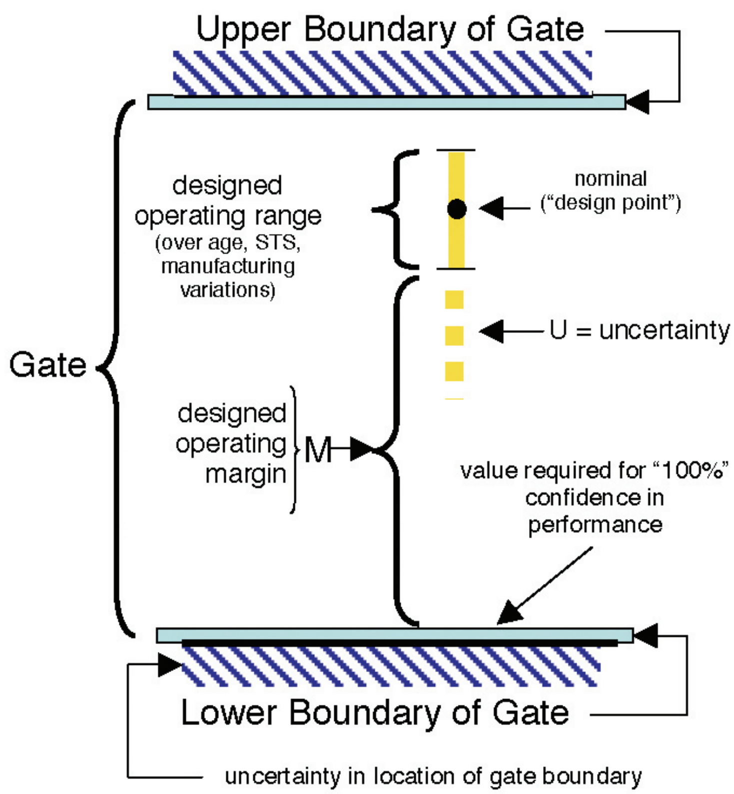

Figure 1—
The main features of a performance gate.

In our full paper [1], we present two ways of formulating QMU that we have termed "Interval" and "Full." The use of either formulation requires approximations and scientific judgment. However, fully probabilistic analyses require knowledge of uncertainties that will usually be difficult to obtain.

"ONE/Not ONE" estimates of reliability are consistent with historical practice. Both approaches are a response to the very limited availability of detailed uncertainty information. Extending this class of estimates to current and future stockpile questions is itself a significant challenge.

The U.S. nuclear weapons community is just beginning to explore where QMU can be useful. The emphasis in QMU on characterization of uncertainties is essential for determining which stockpile questions can be answered with confidence using the data and simulation capabilities that are available at any given time. Improvements in predictive science may allow improved estimates of uncertainties, and potentially may also allow them to be reduced. This would affect the scope of questions that can be dealt with successfully, but significant limitations are expected to remain. Identifying these limits is an important task of the nuclear weapons program.

We submit that when carefully applied, QMU can improve our basis for assessing the reliability of stockpile decisions.

[1] D.H. Sharp, T.C. Wallstrom, and M.M. Wood-Schultz, "Physics Package Confidence: 'ONE' vs '1.0'," Los Alamos National Laboratory report LA-UR-04-0496 (January 2004); presented as a poster at NEDPC 2003.